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(54) Thermal ink jet printhead.

(57) A thermal ink jet printer has a nozzle (17,19), a heating element (15) within the nozzle and an ink well (11) within the thickness of a rigid substrate (10) carrying the nozzle and heating element. The latter are produced by deposition on the substrate. Thus the well (11) is directly adjacent to the nozzle (17), avoiding cavitation problems, destruction of the element (15) by ink turbulence. The method of production is described.

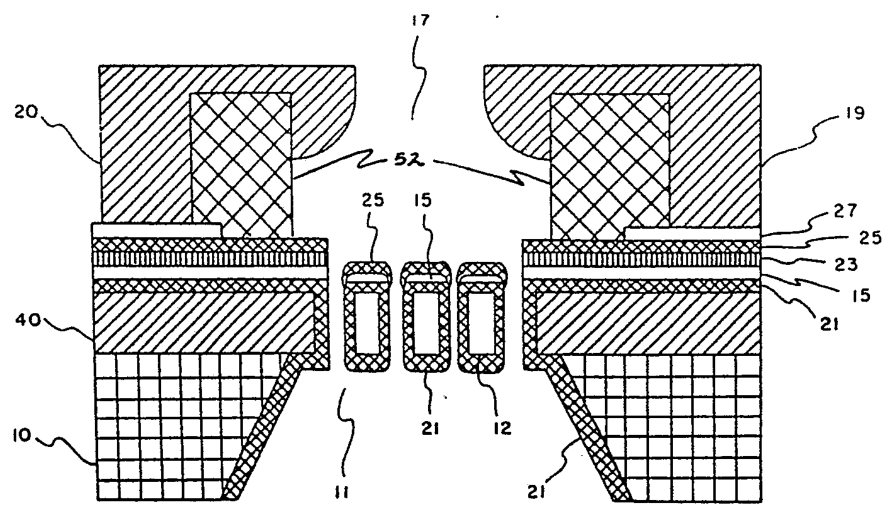

FIG. 3

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Thermal Ink Jet Printhead

This invention concerns thermal ink jet (TIJ) printheads, and to methods for their manufacture.

TIJ printheads employ a liquid ink in a reservoir or well, the ink being fed via passages to a series of nozzles defined by a nozzle plate. Within each nozzle is a resistive heater which is independently energizable to evaporate the ink which emerges from the nozzle under pressure.

Difficulties which arise with known printheads include detachment or misalignment of the nozzle plate which has been glued in place after formation of the heater and the structure of the well and passages; restricted ink flow through the passages, thus slowing the rate of printing; and unrealiability due to destruction of the resistive heater by the flow of ink and the cavitation forces of the expelled vapour.

US Patent No. 4438191 proposes a new form of TIJ printhead which is an improvement on previous printheads. However, the fabrication of this device presents additional problems: formation of ink holes, removal of dry film residue from the firing chambers and other locations, proper alignment of the nozzle, and various manufacturing problems. Also, the nozzles of the monolithic printhead do not diverge. The present invention aims to reduce or avoid some or all the disadvantages mentioned above.

According to a first aspect ofthe present invention there is provided a monolithic ink jet printhead for ejecting a substance comprising a nozzle enclosing a heating chamber, means for storing the substance contiguous with the heating chamber, and a heating element for propelling the substance through the nozzle, characterised in that means is provided for flexibly supporting the heating element within the flow of the substance.

A monolithic printhead has the advantages of lower cost and increased precision. An advantage of placing the heating element within the flow of the substance is that the substance (e.g. ink) buffers the heating element from cavitation forces that result from collapsing bubbles. These cavitation forces could otherwise destroy the heating element. Additionally, the supporting means can flex and absorb energy from the collapsing bubbles that would otherwise be absorbed by the heating element.

In a preferred printhead the storing means is brought directly adjacent the nozzle, and there is then no restriction on the rate of ink flow which permits an increased printing speed. Preferably, the nozzle and heating element are formed integrally on a substrate by deposition techniques. This ensures automatic alignment of the nozzle, and means the nozzle plate cannot be detached.

According to a second aspect of the present invention there is provided a method of producing a monolithic ink jet printhead comprising the steps of: using integrated circuit techniques to construct in a first part of a substrate a means for supporting a heating element, using integrated circuit techniques to form in a second part of the substrate a means for storing ink that is contiguous with the supporting means, using integrated circuit techniques to form a heating element on the supporting means, and using integrated circuit techniques to form nozzle on the substrate and over the heating element.

By constructing the entire printhead, including the nozzles, using integrated circuit techniques, precise nozzle alignment with the rest of the printhead is obtained. This precise alignment increases the allowable nozzle density and permits the construction of a page width array of nozzles, Also, by using integrated circuit techniques, batches of printheads can be made at one time.

In order that the invention shall be clearly understood, exemplary embodiments thereof will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a prior-art thermal ink jet printhead;

Figure 2A shows a cross section of a prior-art nozzle on line A-A in Fig 2B;

Figure 2B shows a top view of a prior-art nozzle, the line A-A corresponds to the cross section of Figure 2A;

Figure 3 shows a cross-section on line A-A in Fig.4 of a preferred embodiment of the invention with cantilever beams;

Figure 4 shows a top view of the preferred embodiment of the invention with the nozzle removed; the line A-A corresponds to the cross-section of Figure 3;

Figures 5A-5C shows steps in preparing the substrate for masking;

Figures 6A-6C shows the formation of the cantilever beams and the well;

Figures 7A, 7B, and 7C show the steps taken to construct the nozzle shown in Figure 3;

Figure 8 shows an alternative embodiment of the invention without cantilever beams.

Figure 9 shows a top view of the alternative embodiment shown in Figure 8.

A prior-art thermal ink jet printhead 2 is shown in Figure 1. The advancement of thermal ink jet technology stumbles upon an assembly problem: detachment of the nozzle plate 1. Presently, each nozzle plate 1 is individually attached with epoxy to

the resistor structure 3 as shown in Figure 2A. This costly procedure is problem-prone. For example, this procedure often misaligns the nozzle plate 1. Figure 2A, a simplified representation of the prior art, omits many of the details. The differences in thermal expansion coefficients among different components of the printhead 2 tend to debond the nozzle plate 1 during the curing process of the glue. This adhesion problem limits the number of nozzles in the printhead 2.

The ink refilling rate of prior-art TIJ print head 2 presents another problem. It limits the printing speed. In prior-art TIJ printheads 2 shown in Figure 2B, ink reaches the nozzle 6 after travelling through high friction channels 7 which restrict the ink flow.

A monolithic thermal ink jet printhead is proposed. This monolithic structure makes page-width array thermal ink jet printheads possible. The monolithic structure can be manufactured by standard integrated circuit and printed circuit processing techniques. A nickel-plating process constructs a nozzle on top of resistors, thereby eliminating adhesion and alignment problems. A rigid substrate supports a flexible cantilever beam upon which the resistors are constructed. The cantilever beams, together with the ink itself, buffers the impact of cavitation forces during bubble collapsing and results in a better resistor reliability. The monolithic printhead allows a smoother ink supply since the ink is fed directly from the backside past the resistor from a well in the thickness of the rigid substrate. The orifice structure is constructed by a self-aligned, two-step plating process which results in compound bore shape nozzles.

Figure 3 shows a cross-section of the preferred embodiment of the invention, a monolithic thermal ink jet printhead with integrated nozzle 19 and ink well 11. Figure 4 shows a top view of the monolithic printhead 20. Within the thickness of the substrate 10 a well 11 resides to hold ink. The heating element, a resistor layer 15, evaporates the ink. The gaseous ink (water vapour, glycol, and ink pigment particles) migrates to the nozzle area 17. The compound bore nozzle 19 directs the gaseous ink as it is expelled from the nozzle area 17 by pressure from the accumulated gaseous ink.

A thermal barrier, layer 21, prevents heat from flowing to nickel cantilever beams 12 which form part of the nickel deposit 40. The beams 12 are formed by apertures which communicate between wall 11 and nozzle 17. Because of layer 21 heat from the resistive layer 15 heats the ink and is not wasted on the printhead 20. A patterned conducting layer 23 shorts out the resistive layer 15 except on the cantilever beams 12. A protective layer 25 prevents electrical shorts during the nickel plating process to form the nozzle 19. The protective layer 25 also protects layers from chemical and mechanical wear. A conducting layer 27 is deposited during the manufacturing process to provide a surface upon which the nozzle 19 can be constructed.

Advantages of the present invention include the automatically-aligned nozzle 19, shown in Figure 3. Prior-art processes misalign the nozzle plate 1 shown in Figure 1. This misalignment causes dot spread and slanted printing. The new monolithic TIJ printhead 20 reduces resistor failure. In prior-art TIJ printheads shown in Figure 1, the collapsing bubble and refilling ink impact the resistor surface. The cavitation force eventually destroys the resistor. In the new monolithic TIJ printhead 20 shown in Figure 3, the collapsing bubble collides with the refilling ink. The ink absorbs most of the cavitation forces. The cantilever beams 12, upon which the heating element, such as a resistor, is built, absorb the remaining cavitation force. The cantilever beams, constructed from ductile nickel, lie in a reservoir of ink. The mechanical forces on resistors will be buffered by the flexibility of the cantilever beams as well as the ink itself.

Also, in the present invention printing speed is not limited by the ink refilling rate. The ink well 11 is directly connected to the heating elements 15 as shown in Figure 3. This direct connection reduces resistance to ink flow. Thus, printing speed is not limited by the ink refilling rate.

Figures 5 to 7 illustrate the process to manufacture monolithic thermal ink jet printheads 20 and involves several steps. On a substrate 10 of glass or silicon shown in Figure 5A, a conducting, layer 30 approximately 1000 A is deposited using a sputter deposition technique. By conducting electricity through the conducting layer 30, a surface is formed to which nickel plating can be attached. Next, a dry film mask 32 is laminated on the conducting layer 30 as shown in Figure 5B. This mask 32, having a diameter of 50.8 to 76.2 µm (2 to 3 mils), defines the location of the cantilever beams 12 in Figure 3 as well as 13 in Figure 8. Figure 5C shows the various shapes a mask 32 can have. Mask 38 corresponds to the printhead 20 shown in Figure 4. Mask 34 corresponds to printhead 60 shown in Figure 9.

Next, an electroplating process deposits a nickel layer 40 from 25.4 to 38.1 um (1 to 1.5 mils) thick onto the exposed substrate 10. Thus, cantilever beams 12 are formed. After completion of, the plating, removal of the dry film mask 38 exposes the cantilever beams 12 shown in Figure 6B. The well 11 is formed through a multi-step process. First, a sputtering process deposits a protective metal layer 42. This layer is made of gold and has a thickness of 1000 Å. Next, a mask 44 defines the well 11. Then, a wet chemical etching process, such as KOH for silicon or HF for glass, forms the well 11. When the protective layer 42 and the mask

layer 44 are removed, the device appears as shown in Figure 6C.

Next, a thermal insulating layer 21, made of LPCVD SiO_2 or another dielectric, is deposited. It is deposited to a thickness of 1.5 µm on the inside of the well 11, on top of the plated nickel layer 40, and around the cantilever beams 12 as shown in Figure 3. The thermal insulation layer 21 encourages the efficient operation of the resistor layer 15. On top of the thermal insulating layer 21, a resistive layer 15 made of a material such as tantalum-aluminium is deposited to a thickness of 1000Å to 3000 Å, as shown in Figure 3. Next, a conducting layer 23 made of gold or aluminium to a thickness of 5000 Å is selectively patterned on resistive layer 15 to short out portions of the resistive layer 15. The conducting layer 23 is not present on the cantilever beam 12 so that the resistive layer 15 is operative there. On top of the conducting layer 23, a protective layer 25 made of Si Carbide (SiC) and Si^3N^4 or other dielectric material is deposited using an LPCVD process. This layer protects the device from chemical and mechanical wear.

A conducting layer 27, 1000 to 5000 Å thick, is deposited on the protective layer 25. It is formed by sputtering. The conducting layer 27 provides a surface upon which the nozzle 19 can be formed with an electroplating process. Next, portions of the conducting layer 27 are etched away through a wet-etching process, so that the only conducting layer 27 remaining is located where the nozzle will be constructed.

Next, donut-shaped dry film blocks 52 are laminated onto the conducting layer 27. These blocks 52 form a frame for the construction of the nozzle 19. In the preferred embodiment of the invention, the nozzle 19 is constructed in a two-step plating process. The results of the first step are shown in Figure 7A. The base of nozzle 19 is formed by electroplating nickel onto the conducting layer 27 to a thickness of 38.1 to 5.08 µm (1.5 mil to 2.0 mil), which equals the height of the nozzle 19. Next, a glass slab or any other flat dielectric material 56 is pressed on the nozzle 19 as shown in Figure 7B. This slab 56 acts as a nozzle 19 mould for the second part of the nickel plating process. Figure 7C, the electroplating process is continued to form the nozzle 19. Now that the nozzle is completed, the slab 56 is removed. The resulting product is the printhead 20 shown in Figure 3.

Other methods can be used to form the nozzle 19. For example, the nozzle 19 could be constructed by a one-step plating process without the use of the slab 56.

Figures 8 and 9 show an alternative embodiment of the printhead 20. A nozzle 19 having this shape is called a compound-bore nozzle 19. It controls the stream of ink ejected from the nozzle 19. The ink stream ejected from a compound-bore nozzle has a narrow diameter and minimum spread. The cantilever beams 13 protrude inward and the heating element 15 rests on top of the cantilever beam 13. This embodiment of the printhead 20 would be formed in the same way as the printhead 20 shown in Figure 3. The primary difference in the process would be in the type of mask 32 used when layer 40 is plated onto substrate 10. Instead of mask 38 for the cantilever beams 12, a mask similar to mask 34 or 36 is used.

In the preferred embodiment of the invention, the printhead ejects ink. This ink contains water, glycol, and pigment particles. However, it can be used to eject other substances.

The present invention, a monolithic thermal ink jet printhead with integrated nozzle and ink well and a process for making it, solves the nozzle attachment and ink flow problems of prior-art printheads mentioned above. Also, the present invention reduces manufacturing costs and improves reliability. The reduced manufacturing costs are partially achieved through an automated manufacturing procedure. The increased reliability is partially achieved through longer resistor life and smoother ink flow in the printhead. With these improvements, page-width TIJ print arrays are possible.

Claims

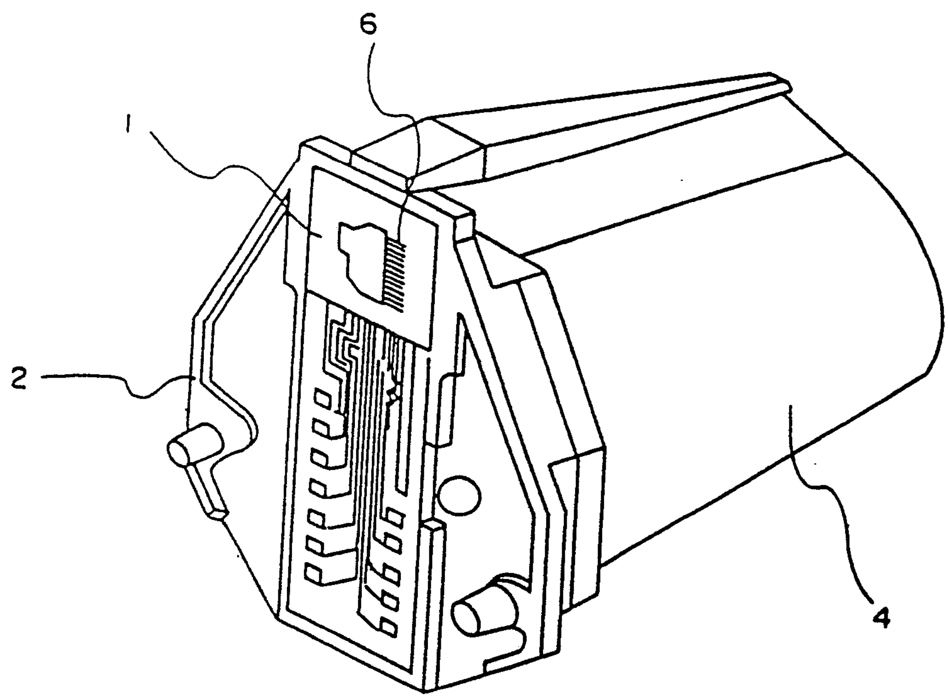
1. A method for accurately aligning an orifice opening (17) in an orifice plate of an ink jet printhead with a transducer element (15) on a thin film substrate member (15,21,23,25,40) of said printhead, comprising the steps of: providing a metal seed layer (27) having an opening therein on said thin film substrate, providing a barrier layer (52) on said thin film substrate and adjacent said opening in said seed layer, providing an opening in said barrier layer and aligning said opening in said barrier layer with said transducer element in said thin film substrate, and plating a metal orifice layer (19) on said metal seed layer and over said barrier layer to form an orifice opening extending within said opening in said barrier layer and aligned thereto, whereby said orifice opening is aligned to both said opening in said barrier layer and to said transducer element in said thin film substrate.

2. A method according to claim 1, wherein the plating of said metal orifice layer includes plating a first orifice plate section (19) over a portion of said barrier layer (27) and then plating a second orifice plate section (19) as an extension of said first orifice plate section to form a convergent nozzle

opening (17) within said opening in said barrier layer and aligned with said transducer element (15).

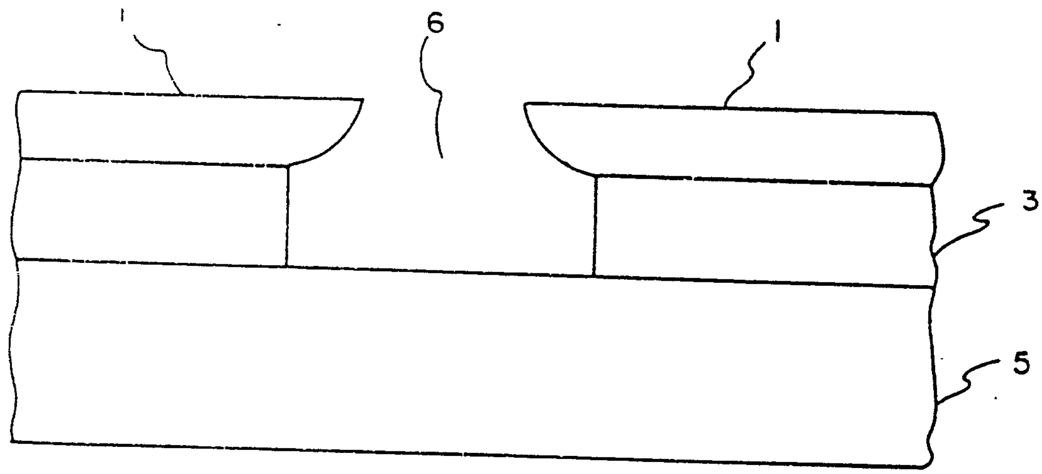
3. An ink jet printhead comprising: a transducer element (15) located within a thin film substrate (15,21,23,25,40) for providing energizing pulses to said transducer element during an ink jet printing operation, a seed layer (27) having an opening therein disposed on said substrate, a barrier layer (52) disposed on said thin film substrate and located adjacent to said opening in said seed layer, said barrier layer having an opening therein aligned with said transducer element, and a metal orifice layer (19) plated up from said seed layer and over said barrier layer and having an orifice opening (17) therein, located within and aligned to said opening in said barrier layer, whereby said opening in said orifice plate is also aligned to said transducer element in said thin film substrate.

4. An ink jet printer incorporating one or more printheads, each comprising one or more orifice openings (17), each aligned with a transducer (15); wherein the orifice openings and transducers are aligned by a method according to claim 1 or 2.



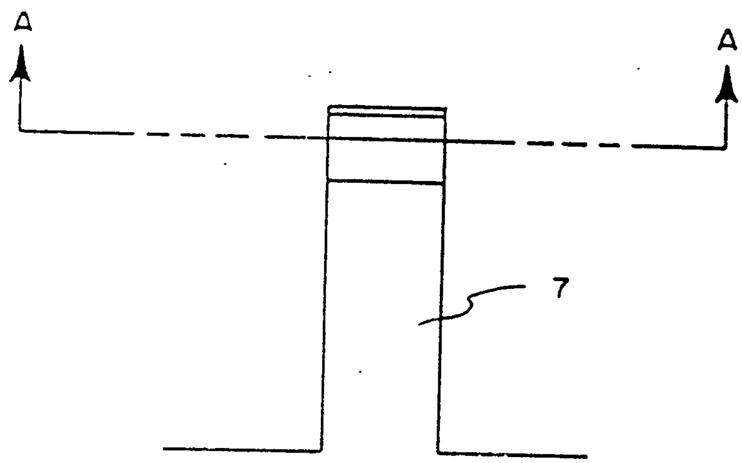
PRIOR - ART

FIG. 1



PRIOR-ART

FIG. 2A



PRIOR-ART

FIG. 2B

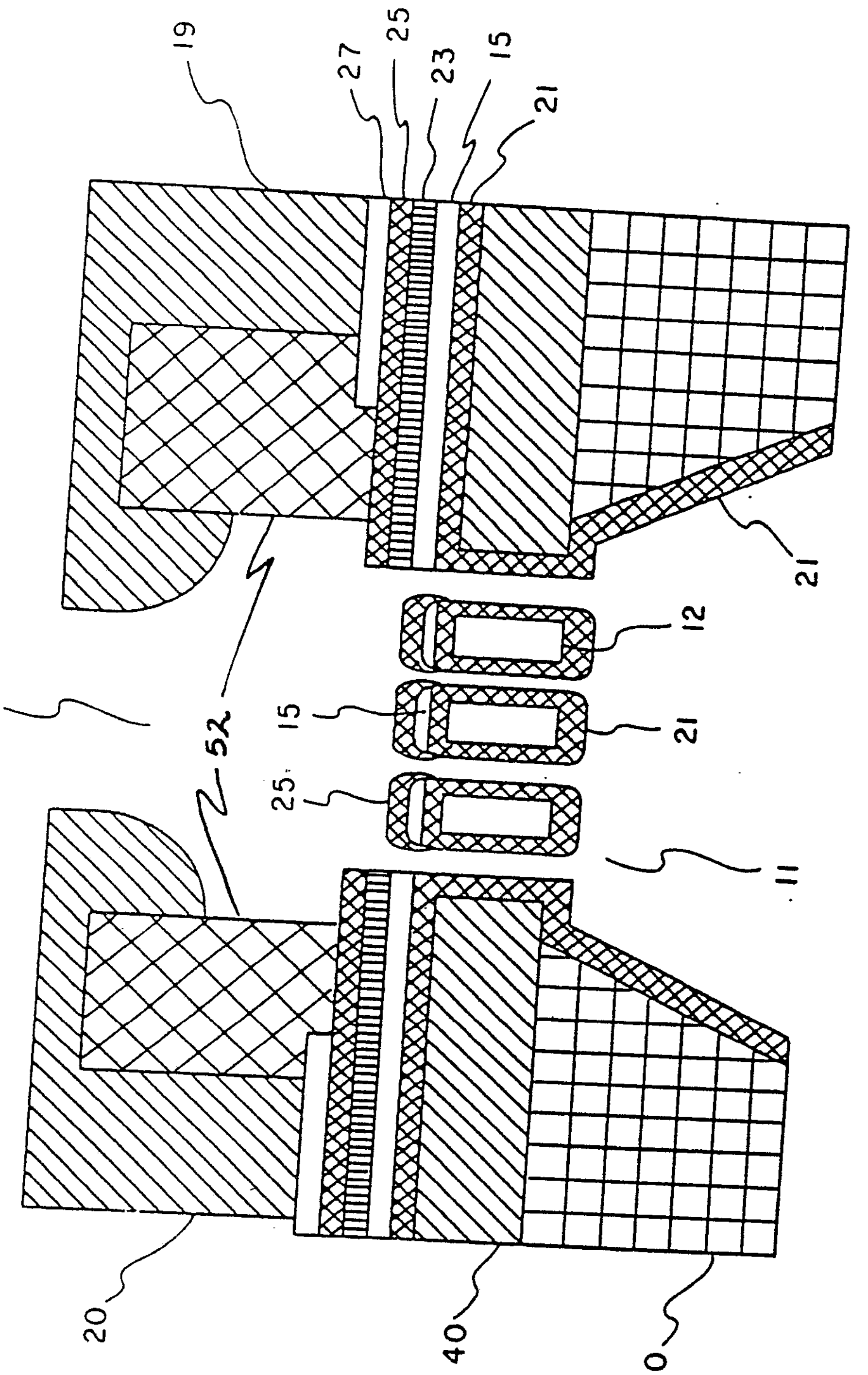


FIG. 3

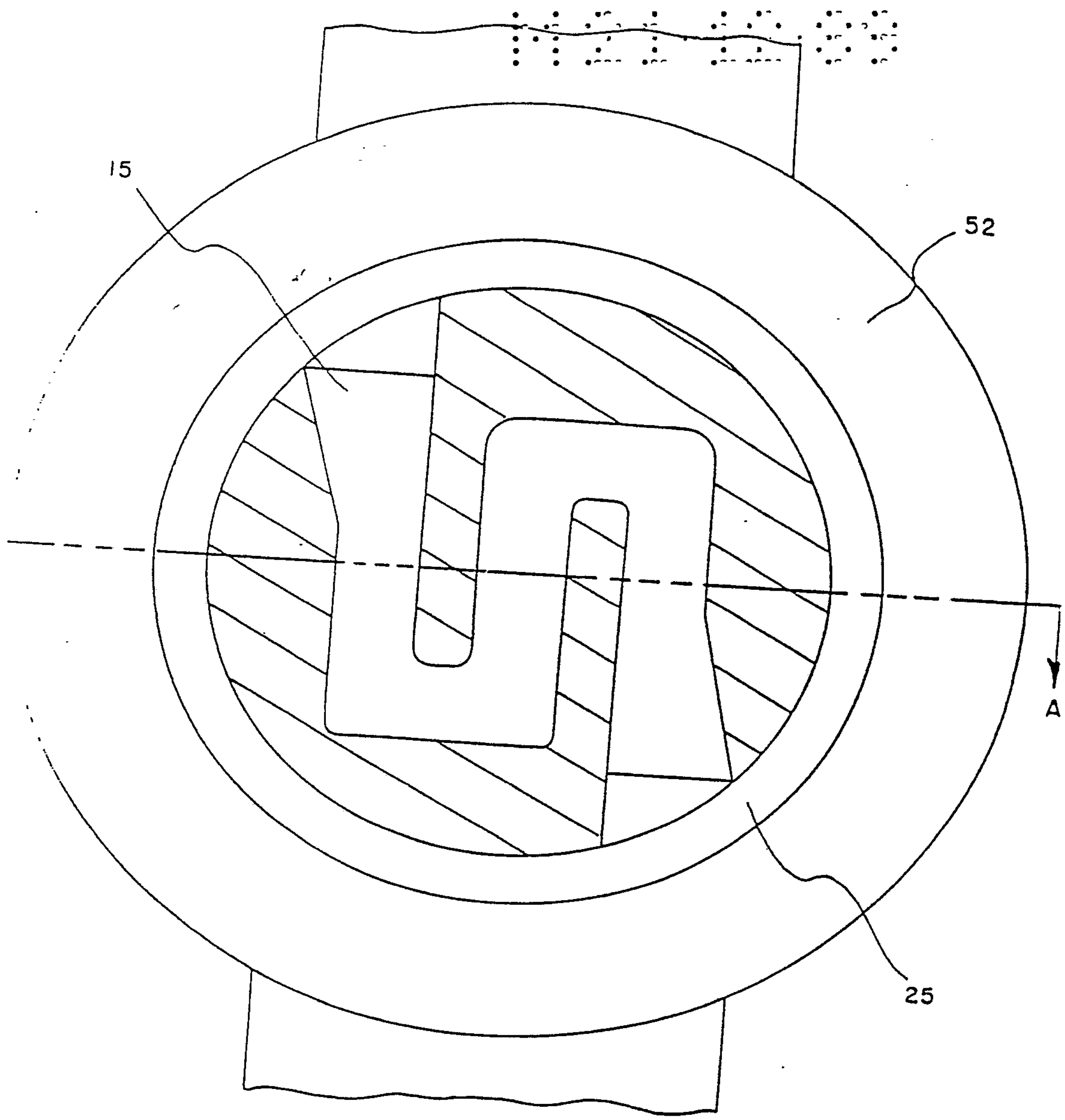


FIG. 4

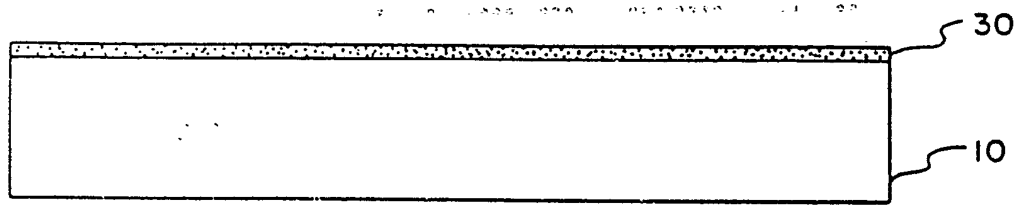


FIG. 5A

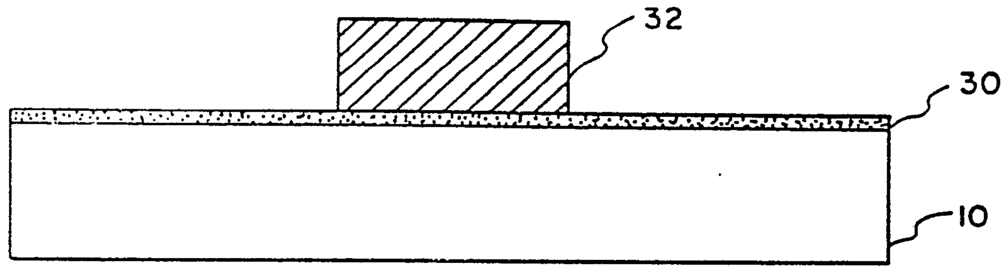


FIG. 5B

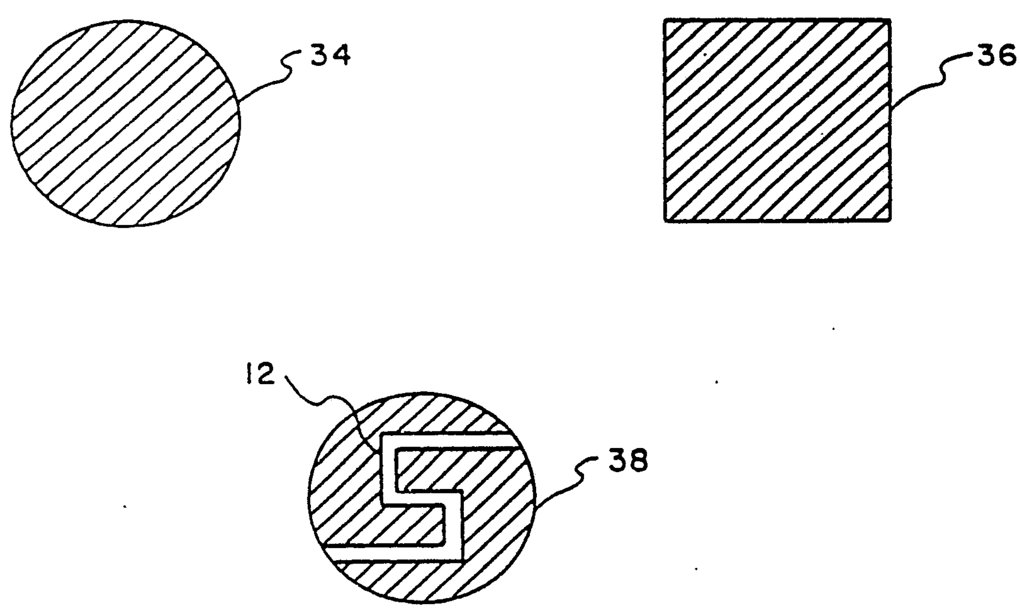


FIG. 5C

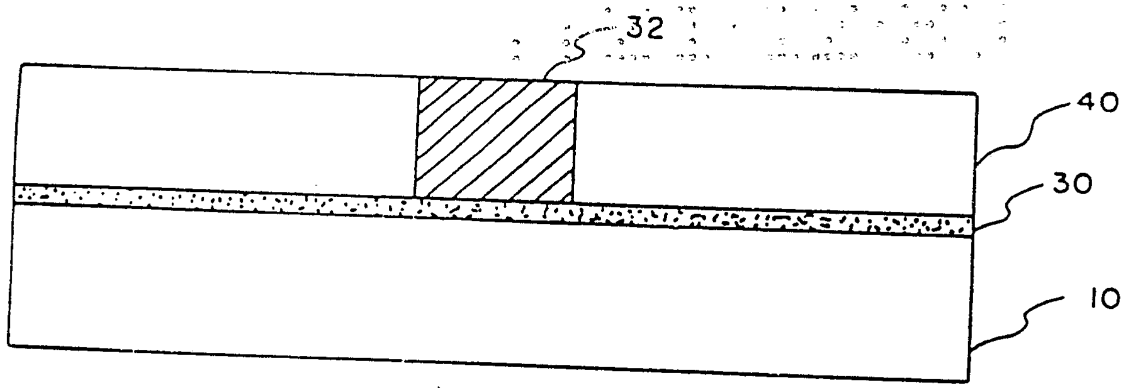


FIG. 6A

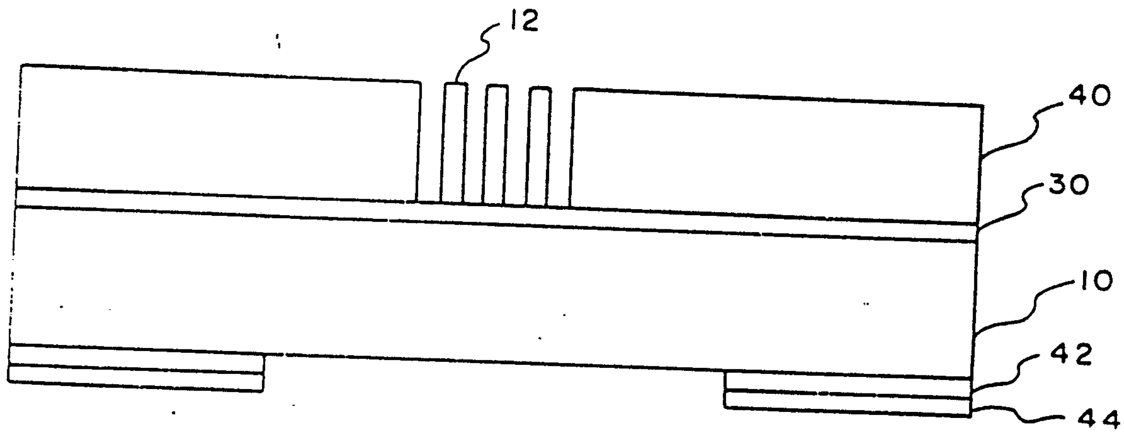


FIG. 6B

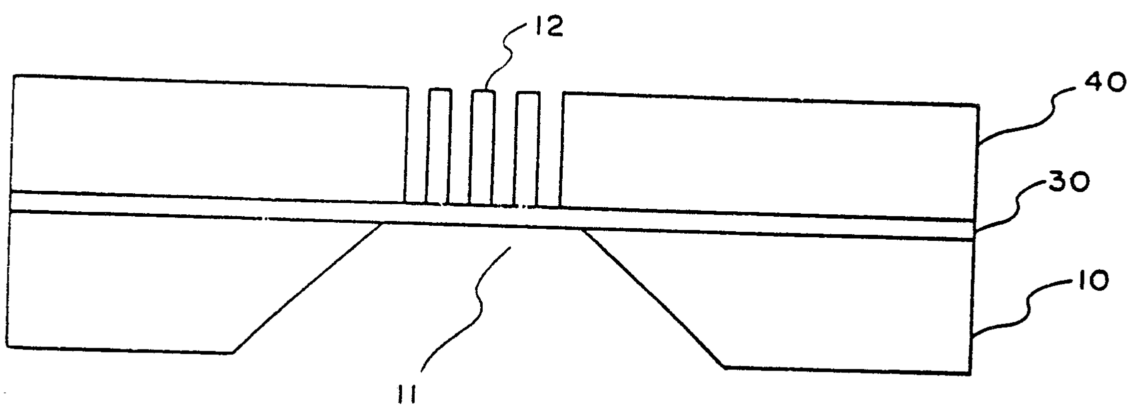


FIG. 6C

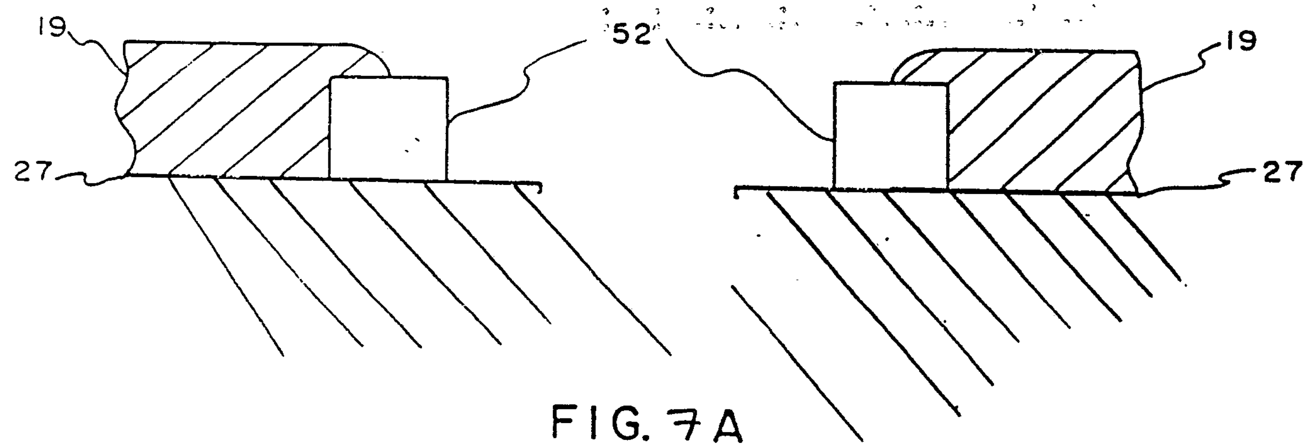


FIG. 7A

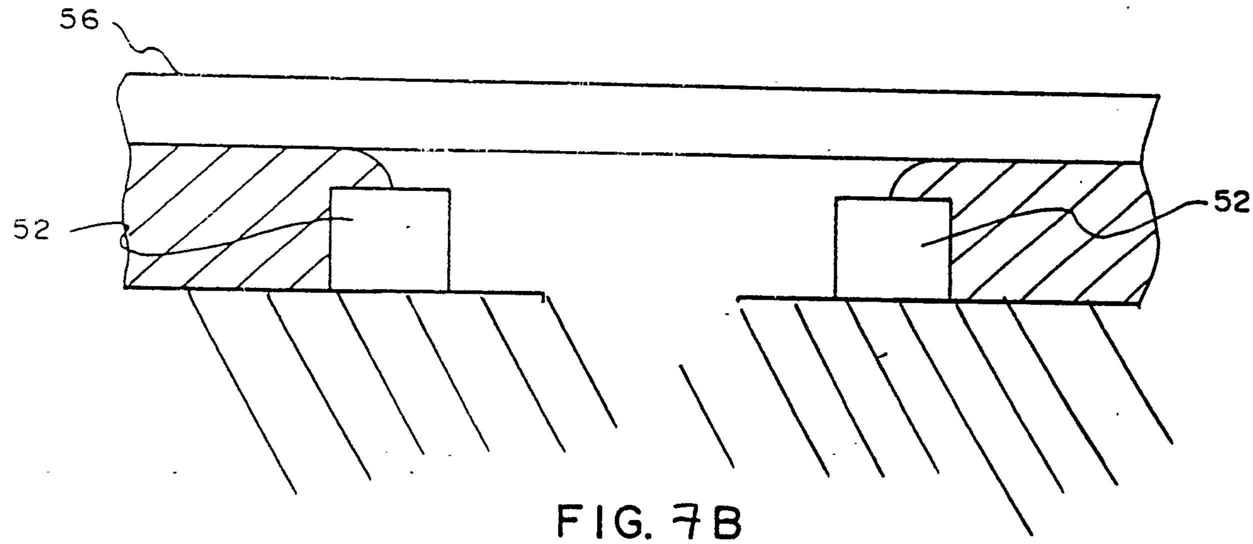


FIG. 7B

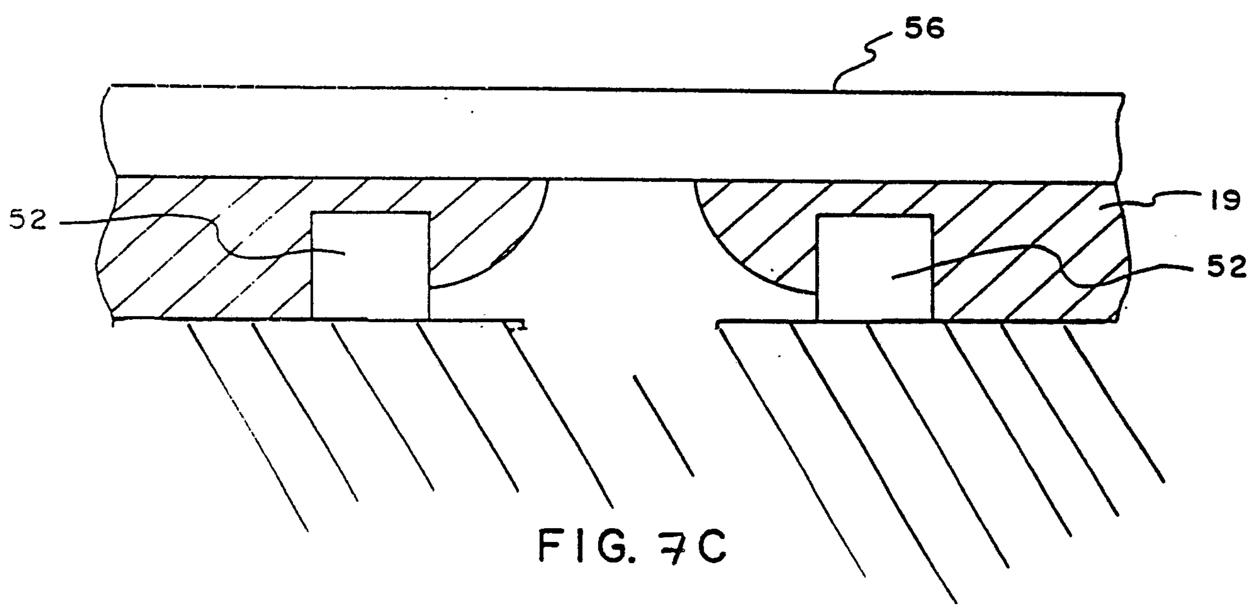


FIG. 7C

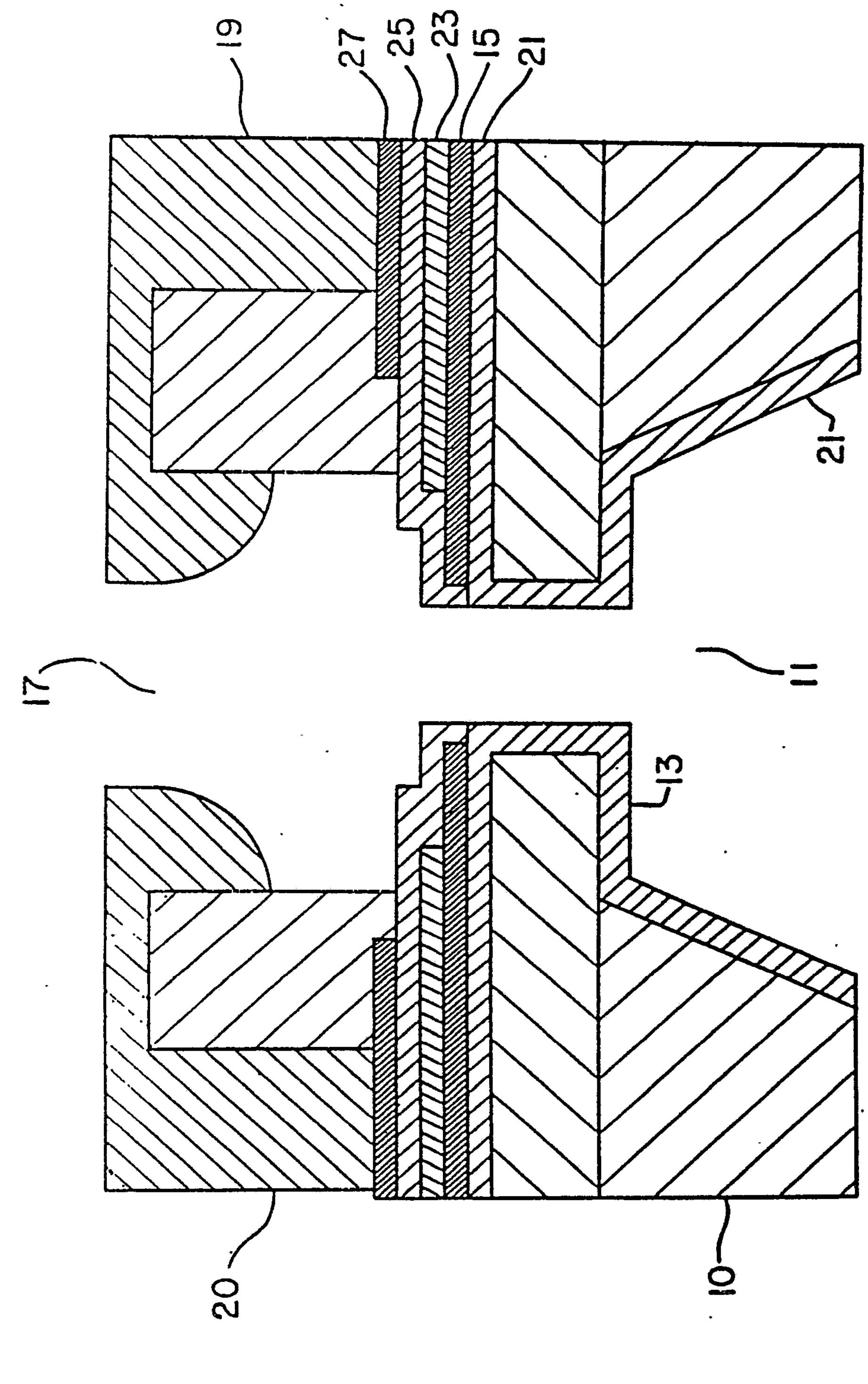


FIG. 8.

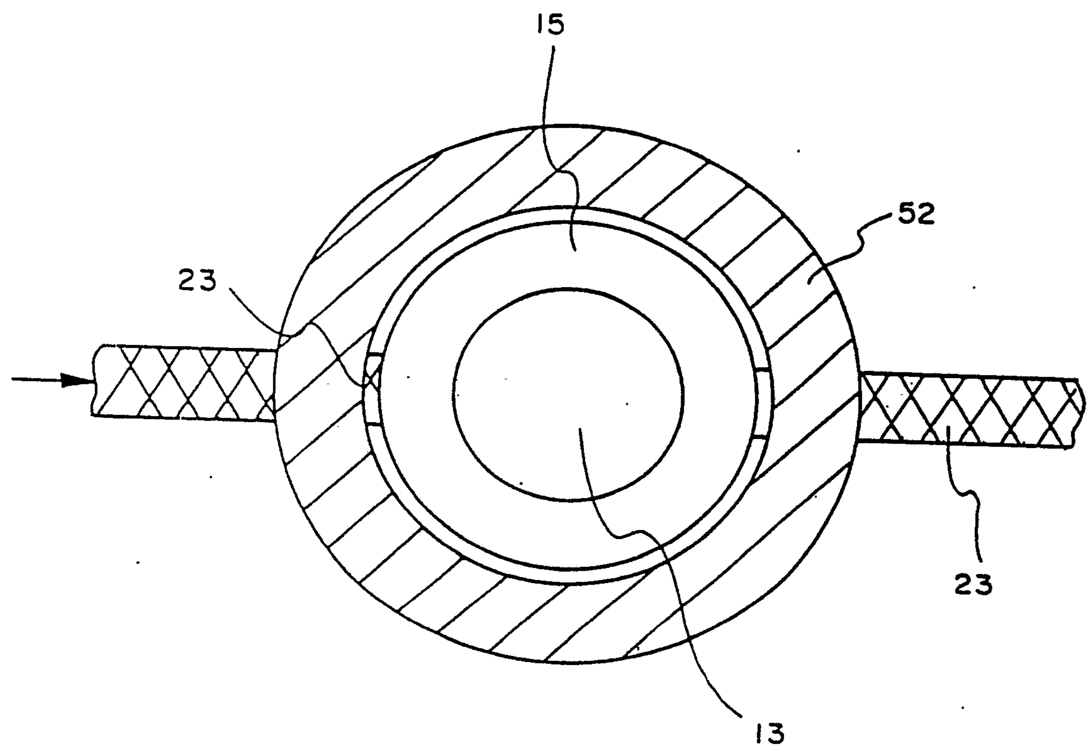


FIG. 9.

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 89123606.9

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 5)
A	EP - A2 - 0 140 611 (HEWLETT-PACKARD) * Page 7, line 24 - page 8, line 19 * --	1,3	B 41 J 2/05 B 41 J 2/14
D,A	US - A - 4 438 191 (CLOUTIER) * Totality * ----	1,3	

TECHNICAL FIELDS SEARCHED (Int. Cl. 5)
B 41 J G 01 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	20-02-1990	WITTMANN

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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